FOR IMMEDIATE RELEASE

NEW AI TOOL AND COMMUNITY INTERVENTION PROGRAMME TO DETECT AND MANAGE EARLY SIGNS OF DEPRESSION IN SENIORS

The AI tool, when developed, will collect and analyse voice recordings to assess seniors' mental health, with their consent.

Singapore, 16 October 2024 – As part of a three-year research study and pilot programme named SoundKeepers, seven partners from the healthcare and social sectors will come together to create an AI tool using voice biomarkers to detect early signs of depression in seniors and a community intervention programme to manage the condition outside healthcare settings.

Just as blood and stool samples are collected to provide doctors with insights into a patient's physical health, a voice biomarker tool collects voice samples to provide clues into the patient's mental health, with consent. When completed and if deemed successful, it is envisioned that the tool and programme will provide professionals and patients with an objective measurement to normalise conversations about a topic that is often hidden, hard to define, and often difficult to talk about.

The seven partners include Nanyang Technological University, Singapore's (NTU Singapore) Lee Kong Chian School of Medicine (LKCMedicine) and College of Computing and Data Science (CCDS); two healthcare institutions of the National Healthcare Group, National Healthcare Group Polyclinics and Institute of Mental Health; two Social Service Agencies, Fei Yue Community Services and Club HEAL; and philanthropic house Lien Foundation. 20 GP clinics in Hougang and Woodlands will also play a supporting role.

Involving over 600 seniors, SoundKeepers aims to help seniors aged 55 years old and above suffering from subsyndromal depression (SSD) – a stage where depressive symptoms start to emerge but are not yet severe enough to warrant a diagnosis. Among seniors, it is a largely unaddressed health risk.

Those with SSD are five times more likely to develop depression within a year and have a 12 times higher risk of dementia. It is one of the most common mental health conditions to affect seniors in Singapore, with 13.4% of community-dwelling seniors older than 60 affected by it, a likely under-estimation as it is based on self-reported assessments. Seniors with SSD incur higher healthcare costs than those without SSD and have comparable use of outpatient services to those with depression. Chronic diseases and disability, conditions that commonly plague seniors, exacerbate SSD.

Compared with depression, SSD is three times more prevalent and has an incidence rate five times greater, i.e., at any point in time, there are three times more people with SSD compared to those with depression and over a one-year period, five times more people develop SSD compared to those who develop depression. Recovery and mortality account for the difference between the prevalence and incidence rates.

“We need new ways to listen to our seniors. While they may not express their worries through words, we can now try to hear it through their voices,” said **Mr Lee Poh Wah, CEO, Lien Foundation.**

“Currently SSD is not actively diagnosed or treated. However, with the focus on early detection and treatment emphasised by both HealthierSG and the National Mental Health and Well-Being Strategy, this project becomes extremely relevant as it can facilitate the early detection and diagnosis of SSD with a tool that can be easily used in the community setting,” said **Dr Mythily Subramaniam, Assistant Chairman, Medical Board (Research), IMH and Co-Principal Investigator of SoundKeepers**.

How the pilot will work

Recruitment of participants will be at Hougang and Woodlands Polyclinics. There will be two components to the programme structure: The collection of voices at the polyclinics and IMH with the development of the voice biomarker tool at CCDS, and a referral process for identified seniors from the polyclinics to the SSAs where they will attend a 24-week community-based early intervention programme.

In the first component, researchers will collect a voice sample of several minutes long from each patient with his or her consent via a casual conversation or passage reading. Many such voices will be used to build the algorithm for detecting SSD using a designated smartphone. Once developed, the voice biomarker will provide an indication of the state of a patient’s mental health of depression or subsyndromal depression in an objective manner, akin in some ways to how doctors currently take readings of a patient's temperature or blood pressure.

Deterioration in mental health often leads to physiological changes in the muscles used in voice production. For example, stress can cause muscle tension in the throat, neck, and jaw, affecting the vocal cords and therefore, the pitch and tone of the voice generated. Strong emotions may lead to physiological arousal such as faster speech or a trembling voice. Shallow or irregular breathing, commonly seen in patients with anxiety, can affect vocal projection and clarity. Insomnia can lead to difficulty in concentrating, affecting speech rate, fluency, and articulation. Fatigue can affect vocal stamina and volume.

AI data models can pick these up via analysis of the acoustic properties in a voice sample, which range from commonly-known ones such as pitch and volume, to lesser-known ones such as timbre, rhythm, shimmer, jitter, Harmonics-to-Noise Ratio, and others. An AI model will be built with a representative sample of the population that comprises the well, patients with subsyndromal depression and patients with depression, as well as in the same patient across time.

“When we use our voice, we are activating and coordinating more than a hundred different muscles and neurobiological processes. A change in speech acoustic features can reveal abnormalities in these neurobiological processes. With the AI voice tool, primary care physicians will be able to identify seniors with SSD faster, without subjecting them to a battery

of questions that may be distressing to seniors. This is a new area of research in the field of mental health that is being led by LKCMedicine. The potential is immense and represents a paradigm shift in the way we screen and diagnose depression," said **Assistant Professor (Clinical Practice) Dr Lee Eng Sing, Clinical Director of Primary Care and Family Medicine Research Programme at Nanyang Technological University, Singapore (NTU Singapore) Lee Kong Chian School of Medicine (LKCMedicine) and the Co-Principal Investigator of SoundKeepers.**

"The SoundKeepers project aims to leverage advanced AI technologies to identify individuals with SSD using their natural voices. This represents a novel area of research, as while previous studies have demonstrated the feasibility of detecting depression through vocal analysis, little work has been done on the more subtle SSD. The project focuses on developing more advanced technologies to address this challenge. The advantage of using voice as a biomarker for depression, including SSD, lies in its non-intrusive nature and broad application," said **Professor Guan Cuntai, President's Chair Professor in Computer Science and Engineering, Deputy Dean of NTU CCDS and Co-Principal Investigator of SoundKeepers.**

Voice biomarkers can be built upon acoustic properties, linguistic properties, or both. Linguistic properties include coherence, repetition and use of specific words. In SoundKeepers, acoustic properties will be mainly used for efficiency and effectiveness, due to the large linguistic diversity in Singapore's population, particularly seniors.

Currently, a patient's mental health is mainly assessed via self-reported data, in the form of questionnaires provided by healthcare and social service professionals to be completed by patients. Accuracy often hinges on the ability of patients to recall accurately, and each patient's subjective assessment. Those who prefer to keep their mental condition under wraps can do so easily by providing inaccurate answers. As a result, healthcare providers sometimes struggle with reconciling questionnaire results with their intuition. This challenge is often accentuated when working with seniors who are reluctant to share their mental health issues.

"Sometimes, clients provide general or 'textbook' answers to the questionnaire we use to screen for mental health conditions, even though we believe they need help based on information they have verbally shared with us previously. When this happens, it becomes challenging for us to follow up and provide the help they need," said **Danny Loke, Head of Community Mental Health Department, Fei Yue Community Services**.

The goal of SoundKeepers is not to replace existing screenings, for the rapport forged through the conversations and manual screenings is vital. Rather, the voice biomarker tool will complement by helping professionals make their assessments with greater confidence and consistency by providing another reference point.

In the past decade, American, Canadian and Chinese startups have been developing voice biomarker technology. Developing a native technology for Singapore, while requiring more effort, will have advantages, making it easier to manage in accordance with national standards of healthcare data protection. All voice samples will be anonymised, stored in a secure central

storage terminal and not on the cloud. In time, it is hoped that the tool will be part of the set of instruments used routinely in a regular doctor's consultation.

"Primary care is often the first point of contact for individuals experiencing mental health issues, even though they may not be aware of their underlying mental health struggles. This tool can help primary care physicians in polyclinics identify these mental health issues early and accurately, enabling a holistic and timely management of both physical and mental health conditions in a non-stigmatising environment. This collaboration also exemplifies National Healthcare Group's ongoing efforts towards making mental health more accessible for Singapore's population." shared **Dr Eugene Chua, Family Physician, Associate Consultant and NHGP Site Investigator of the SoundKeepers programme.**

The second component of the pilot is a 24-week community-based early intervention programme where the polyclinics will refer patients to the SSAs. Co-developed by IMH, NHGP and the SSAs, it will comprise psychoeducation, community activities, and befriending. Psychoeducation will come in the form of 7 modules that will equip individuals with a range of strategies and techniques to combat SSD. Some of these strategies include making lifestyle changes such as exercising more frequently and eating well, as well as learning ways to establish achievable goals and identifying a trusted confidant who can help them tide through emotionally challenging periods.

Seniors will also be encouraged to participate in community activities that improve sociability and mood, such as exercise, outings, skills learning, recreational activities, and assistance with job search. The simplicity of these activities is intentional: They are selected precisely because they are low-intensity, cost-efficient and short-term, which will aid adoption and scalability of the programme. Staff from the SSAs will check in with the seniors every fortnight in the first 12 weeks and monthly for the next 12 weeks.

"Mental health conditions do not always require therapy and medication. Psychoeducation which can guide people to practice mindfulness, and teach them how to solve their problems proactively as well as social prescription that can lead to a flourishing social circle and active lifestyle may be enough to treat milder conditions and what is pathbreaking is that they can be done in the community," said **Dr Mythily Subramaniam,** who is also an Associate Professor at LKCMedicine.

As part of the pilot, IMH will run the community intervention programme, assess its feasibility and effectiveness, as well as train the SSAs to deliver the modules. Evaluation will involve comparing levels of loneliness, anxiety, well-being and depression literacy among seniors with SSD before and after the intervention.

"In mental health, it is important to intervene early before a condition escalates. The challenge is that there are not many effective ways to do so, which is what we hope SoundKeepers will change. Through it, seniors can potentially benefit from a seamless continuum of care – from early detection at the polyclinics to comprehensive, community-based interventions," said

Rabi'atull Syerida Juma'at, Manager of the Recovery Wellness Programme (RWP) of Club HEAL.

Randomised Controlled Trial

NHGP will helm the randomised controlled trial and recruit 300 seniors with SSD from polyclinics and GP clinics in Hougang and Woodlands. At the end of the intervention programme, the research team will study and evaluate the effectiveness of the interventions. The evaluation and findings will include comparing levels of loneliness, anxiety, well-being and depression literacy among seniors with SSD before and after the intervention as compared to those from the control group.

"The goal is for SoundKeepers, if successful, to eventually become part of the national mental health ecosystem, perhaps in the form of a 'CREST Plus', slotting in between CREST and COMIT," said **Mr Lee Poh Wah.**

CREST and COMIT are two key government-funded community mental health programmes that serve the general public who are at risk of mental illness (in the case of CREST) and those with mental health needs (in the case of COMIT). SoundKeepers may raise the efficacy of CREST in this manner: Many who attend the mental health awareness activities organised under CREST will presumably suffer from SSD, given its high prevalence and incidence rates. Some will indeed step forward to seek help, but it is likely a large proportion will remain hidden due to the lack of tools and workflows that allow professionals to address SSD in a structured manner. With a voice biomarker tool, however, CREST professionals will be able to identify seniors with SSD more confidently and persuade them to seek help, since having SSD, by definition, does not equate diagnosis of a mental illness.

Mr Lee Poh Wah added: "It is possible that in time, voice biomarkers can democratise mental health assessment and monitoring. These could be for stressed parents of children with special needs, patients newly-diagnosed with serious illnesses, etc. Mental health is deeply interconnected with physical health, and should be integrated across the prevention, diagnosis, and treatment of every disease."

The project will receive $5.6m in funding from the Lien Foundation, as well as in-kind support from the partner organisations. After completion, it is hoped that SoundKeepers will be expanded to more polyclinics, GP clinics, and patient profiles.

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About Lien Foundation
The Lien Foundation is a Singapore philanthropic house noted for its model of radical philanthropy. It breaks new ground by investing in innovative models of care, convening strategic partnerships and catalysing action at the intersection of health and social care. The Foundation's focus areas include palliative care, aged care, and child & maternal health. For more information, visit www.lienfoundation.org.

About Nanyang Technological University, Singapore
A research-intensive public university, Nanyang Technological University, Singapore (NTU Singapore) has 35,000 undergraduate and postgraduate students in the Business, Computing & Data Science, Engineering, Humanities, Arts, & Social Sciences, Medicine, Science, and Graduate colleges.

NTU is also home to world-renowned autonomous institutes – the National Institute of Education, S Rajaratnam School of International Studies and Singapore Centre for Environmental Life Sciences Engineering – and various leading research centres such as the Earth Observatory of Singapore, Nanyang Environment & Water Research Institute and Energy Research Institute @ NTU (ERI@N).

Under the NTU Smart Campus vision, the University harnesses the power of digital technology and tech-enabled solutions to support better learning and living experiences, the discovery of new knowledge, and the sustainability of resources.

Ranked amongst the world's top universities, the University's main campus is also frequently listed among the world's most beautiful. Known for its sustainability, NTU has achieved 100% Green Mark Platinum certification for all its eligible building projects. Apart from its main campus, NTU also has a medical campus in Novena, Singapore's healthcare district.

For more information, visit www.ntu.edu.sg

About National Healthcare Group Polyclinics
National Healthcare Group Polyclinics (NHGP) forms the primary healthcare arm of the National Healthcare Group (NHG). Its nine polyclinics serve a significant proportion of the population in the central and northern regions of Singapore.

NHGP provides a comprehensive range of health services for the family, functioning as a one-stop health service centre providing treatment for acute medical conditions, management of chronic diseases, women & children services and dental care. The focus of NHGP's care is on health promotion and disease prevention, early and accurate diagnosis, disease management through physician-led team-based care as well as enhancing the capability of Family Medicine through research and teaching.

Through the Family Medicine Academy and the NHG Family Medicine Residency Programme, NHGP plays an integral role in the delivery of primary care training at medical undergraduate and post-graduate levels. With the Primary Care Academy, NHGP provides training to caregivers and other primary care counterparts in the community sector.

More information is available at www.nhgp.com.sg.

About the Institute of Mental Health

The Institute of Mental Health (IMH), a member of the National Healthcare Group, is the only tertiary psychiatric care institution in Singapore. Located on the sprawling 23-hectare campus of Buangkok Green Medical Park in the north-eastern part of Singapore, IMH offers a multidisciplinary and comprehensive range of psychiatric, rehabilitative and therapy services in hospital-based and community-based settings. The 2,000-bedded hospital aims to meet the needs of three groups of patients – children and adolescents (aged below 19 years), adults and the elderly. Besides providing clinical services, IMH dedicates resources to carry out mental health promotion and raise mental health literacy. IMH also leads in mental health research and training the next generation of mental health professionals in Singapore. For more information, please visit www.imh.com.sg.

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About Fei Yue Community Services

Fei Yue Family Service Centre was established in 1991, followed by Fei Yue Community Services in 1996.

Fei Yue is committed to its mission to effect life transformation through the provision of high-quality social services. Over the years, Fei Yue has consistently delivered its purpose to serve and support various segments of the community, including children, families, seniors, and individuals in need.

Annually, we serve over 82,000 beneficiaries and have impacted their lives for the better across over 48 centres that Fei Yue operates nationwide.

About Club HEAL

Club HEAL was formed in 2012 by a group of like-minded individuals who have a strong passion in helping people with mental health conditions regain confidence in themselves and work towards community reintegration. Club HEAL also supports and enables their families to provide better care during their recovery journey. We promote healing and recovery by inspiring Hope, Empowering lives, fostering Acceptance and spreading Love. Our services include day recovery activities, counselling, home visits, public education, support groups and volunteer training. We are a member of the National Council of Social Service (NCSS), and a part of the Community Intervention Team (COMIT) and Community Outreach Team (CREST) programmes under the Community Mental Health Masterplan developed by the Agency for Integrated Care (AIC), together with the Ministry of Health (MOH).

FACTSHEET

Programme name	SoundKeepers
Programme duration	August 2024 – July 2027 (3 Years)
Partners	• Lien Foundation • Nanyang Technological University, Singapore (NTU Singapore) Lee Kong Chian School of Medicine (LKCMedicine) • NTU Singapore College of Computing and Data Science (CCDS) • National Healthcare Group Polyclinics (NHGP) – Hougang Polyclinic and Woodlands Polyclinic • Institute of Mental Health (IMH) • Fei Yue Community Services • Club HEAL • 20 GP clinics in Hougang and Woodlands (supporting role)
Overview	The SoundKeepers programme aims to identify and address early symptoms of depression via early screening and community intervention, at a stage known as subsyndromal depression (SSD) – when signs of depressive symptoms emerge but are not severe enough to be diagnosed as major depression. SoundKeepers seek to tackle this via the development of two components over three years: 1) **First Component: A Unique AI Screening Tool** In place of typical biomarkers such as blood samples, the AI tool will collect voice recordings as a biomarker, providing a non-invasive, affordable and convenient method to assess whether a senior has no depression, SSD, or syndromal depression. It will provide healthcare providers with an objective tool less vulnerable to biases from self-reporting, and be designed to be normalised in the way blood pressure-taking is accepted today. 2) **Second Component: A 24-week Community-Based Early Intervention Programme** Staff from Social Service Agencies (SSAs) known as Health Companions (HCs) will support seniors with SSD by matching them to community activities, providing them with psychoeducation that has been co-developed by IMH and NHGP. In the later stages of the programme, they will use the AI tool, after it has been validated, to track progress or deterioration.
Research Studies and Timeline	The development of the intervention programme and AI screening tool will involve **three research studies** and impact evaluation over three years.

	<u>Study 1 – August 2024 to September 2025 (14 months)</u> ● Development of the intervention will be led by IMH. The intervention consists of (i) Psychoeducation: 7 modules that will teach seniors a range of strategies and techniques to combat SSD. (ii) Social prescription: HCs will match seniors to community activities of their interest and encourage their participation. ● IMH will deliver the psychoeducation in the pilot study and train SSAs for Study 3 ● Recruitment of seniors with SSD to be undertaken by NHGP and NTU LKCMedicine ● Club HEAL and Fei Yue Community Services will be supporting seniors in the community during the intervention programme ● Exploring the acceptability, feasibility, and appropriateness of the community psychoeducation and activities intervention among seniors with SSD will be led by NHGP and LKCMedicine <u>Study 2 – August 2024 to July 2027 (3 years)</u> ● Develop and validate the voice biomarker algorithm in distinguishing and classifying the different states of depression among seniors in Singapore. ● Carried out by NTU CCDS, NHGP, and IMH. ● Individuals with a depression diagnosis will be recruited at IMH while individuals with no or subsyndromal depression will be recruited at NHGP for the collection of voice samples of these three groups. <u>Study 3 – May 2024 to July 2026 (26 months)</u> ● Conduct a randomised controlled trial (RCT) involving a larger group of seniors over a longer duration, involving community psychoeducation and activities intervention. ● Evaluate the effectiveness of the interventions for seniors with SSD from the control and treatment (SSD) groups ● Compare levels of loneliness, anxiety, well-being and depression literacy among seniors with SSD before and after the intervention as compared to those from the control group. ● Monitor the mental health statuses of all participants with the newly developed voice biomarker AI tool ● Managed by NHGP, IMH, NTU LKCMedicine, NTU CCDS ● Recruitment of seniors with SSD from polyclinics and GP clinics to be undertaken by NHGP and LKCMedicine respectively while community psychoeducation and activities interventions to be conducted by Club HEAL and Fei Yue Community Services.

Effort Sizing /Demographics	Recruitment of seniors ≥ 55 years old to participate in the three research studies will take place at Woodlands Polyclinic, Hougang Polyclinic, GP clinics in Hougang and Woodlands and IMH. Participating seniors will be identified based on self-reported assessments including: ● PHQ-9: Patient Health Questionnaire (31) ○ Depressive levels (helps with the categorisation of no depression, SSD, depression) ● GAD-7: Generalised Anxiety Depression ○ Anxiety levels A database of at least 630 voice samples will need to be collected over the course of three years to suffice for a credible voice biomarker tool. It is more important that the voice samples are representative of the population, than for the total number of voices collected to be large. **Study 1** ● Target yield of seniors to engage – 30 **Study 2** ● Target yield of participants to engage – at least 300 (May be increased up to 1000 to help refine and improve the algorithm) ○ 100 diagnosed with depression ○ 100 diagnosed with SSD ○ 100 non-depressed **Study 3** ● Target yield of seniors to engage – at least 300 randomised to: ○ 150 treatment ○ 150 control
Sample Criteria	To attain such a representation, stringent inclusion, exclusion and exit criteria in recruitment is required. **<u>Inclusion Criteria</u>** <u>Study 1:</u> ● Seniors 55 years old and above diagnosed to have SSD <u>Study 2:</u> ● Adults 21 years and above with no depression, SSD or depression

	<u>Study 3:</u> • Seniors 55 years old and above diagnosed to have SSD **<u>Exclusion criteria</u>** • Is actively being followed up by a mental health professional • Is on psychotropic or psychotherapeutic medication • Has physical difficulties or difficulty with speech, sight and hearing or mobility that may prevent the engagement of activities • Has other mental disorders • Has suicidal tendencies **<u>Exit criteria:</u>** Did not turn up for three consecutive activities or psychoeducation sessions Total projected no. of seniors to approach – **11,233** Total yield of seniors by the end of Study 3 – at least 630
Impact Evaluation	The study will evaluate the residual effect of the intervention 12 months after the start of intervention, and cost effectiveness analysis.
Spokesperson Quotes	"We need new ways to listen to our seniors. While they may not express their worries through words, we can now try to hear it through their voices," said **Mr Lee Poh Wah, CEO, Lien Foundation.** "Currently SSD is not actively diagnosed or treated. However, with the focus on early detection and treatment emphasised by both HealthierSG and the National Mental Health and Well-Being Strategy, this project becomes extremely relevant as it can facilitate the early detection and diagnosis of SSD with a tool that can be easily used in the community setting," said **Dr Mythily Subramaniam, Assistant Chairman, Medical Board (Research), IMH and Co-Principal Investigator of SoundKeepers**. "When we use our voice, we are activating and coordinating more than a hundred different muscles and neurobiological processes. A change in speech acoustic features can reveal abnormalities in these neurobiological processes. With the AI voice tool, primary care physicians will be able to identify seniors with SSD faster, without subjecting them to a battery of questions that may be distressing to seniors. This is a new area of research in the field of

mental health that is being led by LKCMedicine. The potential is immense and represents a paradigm shift in the way we screen and diagnose depression," said **Assistant Professor (Clinical Practice) Dr Lee Eng Sing, Clinical Director of Primary Care and Family Medicine Research Programme at LKCMedicine and the Co-Principal Investigator of SoundKeepers.**

"The SoundKeepers project aims to leverage advanced AI technologies to identify individuals with SSD using their natural voices. This represents a novel area of research, as while previous studies have demonstrated the feasibility of detecting depression through vocal analysis, little work has been done on the more subtle SSD. The project focuses on developing more advanced technologies to address this challenge. The advantage of using voice as a biomarker for depression, including SSD, lies in its non-intrusive nature and broad application," said **Professor Guan Cuntai, President's Chair Professor in Computer Science and Engineering, Deputy Dean of NTU CCDS and Co-Principal Investigator of SoundKeepers.**

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"Primary care is often the first point of contact for individuals experiencing mental health issues, even though they may not be aware of their underlying mental health struggles. This tool can help primary care physicians in polyclinics identify these mental health issues early and accurately, enabling a holistic and timely management of both physical and mental health conditions in a non-stigmatising environment. This collaboration also exemplifies National Healthcare Group's ongoing efforts towards making mental health more accessible for Singapore's population." shared **Dr Eugene Chua, Family Physician, Associate Consultant and NHGP Site Investigator of the SoundKeepers programme.**

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	milder conditions and what is pathbreaking is that they can be done in the community," said **Dr Mythily Subramaniam,** who is also an Associate Professor at LKCMedicine. "In mental health, it is important to intervene early before a condition escalates. The challenge is that there are not many effective ways to do so, which is what we hope SoundKeepers will change. Through it, seniors can potentially benefit from a seamless continuum of care – from early detection at the polyclinics to comprehensive, community-based interventions," said **Rabi'atull Syerida Juma'at, Manager of the Recovery Wellness Programme (RWP) of Club HEAL.** "The goal is for SoundKeepers, if successful, to eventually become part of the national mental health ecosystem, perhaps in the form of a 'CREST Plus', slotting in between CREST and COMIT," said **Mr Lee Poh Wah.** **Mr Lee Poh Wah added:** "It is possible that in time, voice biomarkers can democratise mental health assessment and monitoring. These could be for stressed parents of children with special needs, patients newly-diagnosed with serious illnesses, etc. Mental health is deeply interconnected with physical health, and should be integrated across the prevention, diagnosis, and treatment of every disease."
Project support	The project will receive $5.6m in funding from the Lien Foundation, as well as in-kind support from the partner organisations.
Research Studies Cited	1. Judd LL, Rapaport MH, Paulus MP, Brown JL. Subsyndromal symptomatic depression: a new mood disorder? J Clin Psychiatry. 1994;55 Suppl:18-28. 2. Subramaniam M, Abdin E, Sambasivam R, et al. Prevalence of Depression among Older Adults—Results from the Well-being of the Singapore Elderly Study. Ann Acad Med Singapore. 2016;45(4):123-133. doi:10.47102/annals-acadmedsg.V45N4p123 3. WHO. Depression and Other Common Mental Disorders: Global Health Estimates. World Health Organization; 2017:24 p. 4. Luppa M, Heinrich S, Matschinger H, et al. Direct costs associated with depression in old age in Germany. J Affect Disord. 2008;105(1-3):195-204. doi:10.1016/j.jad.2007.05.008

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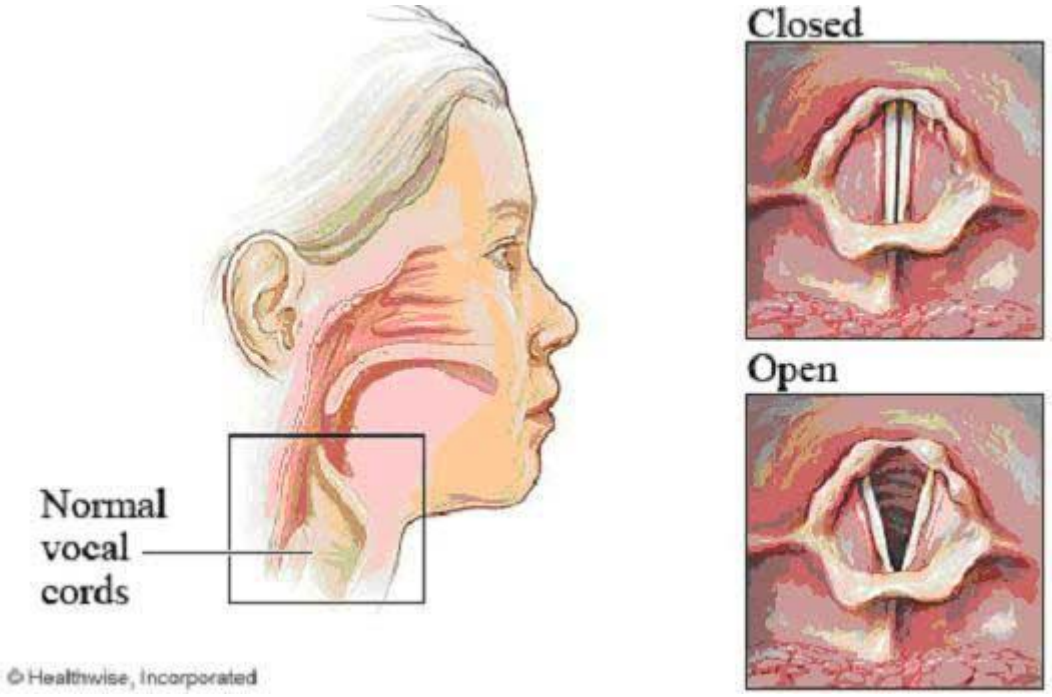
Information on how the larynx works and acoustic variations that are related to SSD and depression	Please refer to Annex A.
Glossary of terms in Mandarin	Please refer to Annex B.

Annex A

1) **How Voice is Produced in the Larynx**



Source: https://www.healthxchange.sg/head-neck/ear-nose-throat/little-known-facts-about-voice#:~:text=When%20exhaled%20air%20from%20the,a%20tiny%20%22buzzing%22%20sound.

The larynx is the voice box. It is made up of the glottis, the vocal cords; the subglottis, which is the area below the vocal cords; and the supraglottis, the area above the vocal cords. The integrity of vocal cords not only affects speech, it also affects breathing as well as the ability to swallow[1].

The ability to speak begins with the breath. The air that reaches the larynx causes the vibration of the vocal cords to create sound. The vocal folds at rest form a 'V' shape and vibrates, opening and closing in oscillation during speech.

2) Acoustic Variations that are Indicators of SSD and Depression

- **Jitter and shimmer**
  Jitter is caused by the lack of control over vocal fold vibration, while shimmer is affected by the tension and stiffness of the vocal cord. Anomalies related to jitter and shimmer are usually heard as hoarseness or breathiness particularly when making long vowels.

- **Timbre**
  Vocal timbre is the perceived quality of the voice, affected by physical characteristics such as sex, height, lung capacity, thickness and length of vocal chords which can change with age, illness or lifestyle habits such as smoking. Studies have found that patients with depression tend to make lower, flatter, softer sounds.

[1] https://www.healthhub.sg/a-z/diseases-and-conditions/larynx-cancer-nccs

- **Rhythm**
  Studies have found that the vocal rhythm flattens and smoothens with fewer variations corresponding to severity of depression.

- **Harmonics-to-Noise Ratio**
  HNR quantifies the ratio between noise and harmonics produced in the voice. The lower the HNR, the lower the quality of the voice. It has also been found that age as well as medication may affect the HNR. HNR typically affects the hoarseness or roughness of the voice.

- **Fundamental Frequency**
  F0 is the frequency at which the vocal cords vibrate when vocal sounds are made and is commonly known as pitch. F0 is affected by the tension and thickness of the vocal cords. It has been found that F0 decreases in patients with depression.

Annex B:

Glossary of terms in Mandarin

Organisation

Lien Foundation		连氏基金会
Lee Kong Chian School of Medicine, NTU Singapore		南洋理工大学李光前医学院
College of Computing and Data Science (CCDS) NTU, Singapore		南洋理工大学计算机与数据科学学院
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Fei Yue Community Services		飞跃社区服务
Club HEAL		
Spokespersons		
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Club HEAL	Rabi'atull Syerida Juma'at, Manager of the Recovery Wellness Programme (RWP) of Club HEAL	

Other Terminology		
1.	AI screening tool	人工智能筛查工具
2.	Biomarker	生物标记物
3.	Chronicity	长期性
4.	Community-based intervention programme	社区干预计划
5.	Community service providers	社区服务机构
6.	Control group	对照组
7.	Depression	抑郁症

8.	Diagnosis	诊断
9.	Dysthymia	癒症
10.	Early intervention	早期介入
11.	Early screening	早期筛查
12.	Exclusion criteria	排除标准
13.	Exit criteria	退出标准
14.	General practitioner clinics	家庭医生诊所
15.	Inclusion criteria	纳入标准
16.	Non-invasive	非入侵性
17.	Physical chronic diseases	慢性生理疾病
18.	Polyclinics	综合诊疗所
19.	Psychoeducation	精神 / 心理教育
20.	Psychotherapeutic	精神 / 心理治疗
21.	Psychotropic	精神药物
22.	Questionnaire	问卷
23.	Randomised controlled trial	随机控制试验
24.	Screening tools	筛查工具
25.	Social dysfunction	社会功能障碍
26.	Social Service Agencies	社会服务机构
27.	Subsyndromal depression	亚综合征抑郁
28.	Syndromal depression	综合症抑郁症
29.	Treatment group	治疗组
30.	Voice biomarker	声音生物标记物
31.	Voice biomarker algorithm	声音生物标记物算法

32.	Voice samples	声音样本